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BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON D. C. 20554

In the Matter of	)	
	)	
	)	
Amendment of Part 90 of the	)	
Commission's Rules to Adopt	)	PR Docket No. 93-61
Regulations for Automatic	)	RM-8013
Vehicle Monitoring Systems	)	

To: The Commission

REPLY COMMENTS OF THE TIA MOBILE & PERSONAL COMMUNICATIONS CONSUMER RADIO SECTION

SUMMARY

The TIA Mobile & Personal Communications Consumer Radio Section ("the Section") respectfully offers its Reply Comments on the *Notice of Proposed Rule Making* ("NPRM") adopted by the Commission on the above-captioned matter. Although the numerous Comments submitted in response to the NPRM reflect a wide variety of perspectives, and address a correspondingly diverse array of issues, the Section focuses here on those issues that in its view are fundamental to the proceeding.

While the Rules proposed in the NPRM distinguish among different types of AVM/LMS systems according to their bandwidths, a number of Comments observed that it is more appropriate to make a distinction on the basis of coverage area. The Section concurs that coverage area (i.e., "wide area" vs. "local area") is a more accurate measure than bandwidth of an AVM/LMS system's function and its ability to coexist with the other occupants in the band.

There seems to be a consensus among commenting parties that wide area systems, such as the wideband pulse-ranging vehicle location system of North American

Teletrac and Location Technologies, Inc. ("Teletrac"), are inherently very sensitive to cochannel interference. Indeed, this sensitivity is the basis for Teletrac's claim that exclusive allocations are needed for wideband pulse-ranging systems. In its Comments on the NPRM, the Section showed that based on the results provided by Teletrac in its Petition which initiated this proceeding, it could be inferred that the Teletrac system could not withstand even the interference from low power Part 15 devices. In its Comments, Teletrac provides new information about its receiver performance which suggests an error in its earlier analysis, or a flaw in the system design itself. This is discussed in detail herein. Teletrac also claims explicitly in its Comments that Part 15 devices do not pose an interference threat to its AVM system. The Section disagrees, based on some simple calculations discussed in these Reply Comments.

Several parties proposed restrictions on either a combination of antenna height and radiated power, or on field strength at some specified distance, to define the limits of local-area AVM/LMS systems (e.g., 10 meters/30 watts). The Section believes that such limits are reasonable. Hughes proposed that the "tags" used in such systems as well as the base transmitters be licensed under Part 90. The Section opposes this proposal.

Several commenters suggested modifications to §15.247 of the Commission's Rules, which governs Part 15 spread spectrum systems operating in the 902-928 MHz band. The Section strongly opposes any such changes, which would devalue the many years and hundreds of millions of dollars that have been applied toward development of these Rules and design of products to comply with them. Further, changes to Part 15 do not fall within the scope of this proceeding.

It was suggested by a number of parties that the most appropriate resolution of this proceeding would be to maintain the status quo. The Section concurs with this, with the stipulation that AVM/LMS operators be prohibited from forcing Part 15 device operators to cease transmission. This would test Teletrac's contention that Part 15 devices are not an interference threat.

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REPLY COMMENTS

INTRODUCTION

1. The Telecommunications Industry Association (TIA) Mobile & Personal Communications Consumer Radio Section ("the Section") hereby offers its Reply Comments on the above-captioned matter. The many sets of Comments submitted in response to the Commission's *Notice of Proposed Rule Making* ("NPRM") represent a broad spectrum of interests and perspectives on this matter. The positions taken by commenting parties range from partial or conditional support of the NPRM to unconditional opposition, and include many suggested modifications to the Commission's proposed Rules. The Section addresses here issues raised in the Comments that, in its judgment, are most fundamental to this proceeding.

AVM/LMS SYSTEMS SHOULD BE DISTINGUISHED ON THE BASIS OF COVERAGE AREA RATHER THAN BANDWIDTH

2. Several parties noted that distinguishing AVM/LMS systems according to their coverage areas is more appropriate than the "wideband/narrowband" distinction made in the NPRM.[1] Others implicitly distinguished between wide and local area systems in their Comments. The Section agrees that the coverage area is more appropriate than bandwidth as an indication of the system's function and its ability to coexist with other occupants of the band.

3. To the Section's knowledge, the "wide area" category would include only wideband pulse-ranging systems such as Teletrac's that require time-of-arrival (TOA) difference estimates from multiple base stations to estimate the position of the transmitter. While design parameters among different wide area AVM systems can vary, the fundamental set of tradeoffs (i.e., bandwidth vs. ranging accuracy) and performance limitations are common to all such systems. These systems tend to use relatively wide bandwidths (several MHz or more) on the return (vehicle-to-network) link and require spectrum relatively free of cochannel interference over a large geographic area to operate reliably, as asserted by Teletrac in its original Petition for Rule Making and by a number of parties in their Comments.

4. The "local area" category includes those systems used for applications such as automatic toll collection. Typically a Part 90 transmitter (e.g., at a toll both) will interrogate a vehicle, which is equipped with a "tag" that receives the signal and responds with the desired information (which might simply be an acknowledgment that the signal was correctly received). Bandwidths and design details vary among members of this category; some of the tags have active transmitters certified under Part 15 of the Commission's Rules, while others are essentially passive devices that use modulated backscatter techniques. The common denominator of such systems is that they all operate over a very restricted area and therefore need relatively little power and are fairly robust against interference.

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1. See Amtech (p. 2), AT&T (pp. 6-7), Hughes (p. 2), Interagency Group (p. 7), Mark IV (p. 6).

5. It is logical to consider the wide area and local area system types separately because they differ significantly with respect to their resistance to interference and their potential to generate interference into other systems. They also provide totally different types of services.

THE VULNERABILITY OF WIDE AREA AVM SYSTEMS TO INTERFERENCE

6. In Appendix 2[2] of its Petition for Rule Making which initiated this proceeding, Teletrac presented analyses demonstrating the extreme vulnerability of the Teletrac system to cochannel interference. These analyses were used to support Teletrac's argument that exclusive spectrum allocations are needed for wideband pulse ranging systems. The analyses showed that even a 10-watt cochannel transmitter near ground level (i.e., mounted on a vehicle) would have a devastating effect on system performance and coverage. The first analysis discussed an idealized case in which four receiver sites were on the corners of a square 10 miles on a side, and the vehicle to be located was at the center of the square. A cochannel interference source was 7000 feet to the left of the upper left base site. Teletrac showed the location estimation error (at the 95th percentile) versus the RF power radiated by the interference source. Multipath was ignored, a fourth-power law path loss was assumed, and the vehicle's unit was assumed to transmit 5 watts via an antenna with an effective gain of -6 dBi.

7. In its Comments, the Section computed the carrier-to-interference ratio (C/I) at each of the four sites versus the radiated RF interference power and plotted it with the location error calculated by Teletrac, as shown in Figure 1 (which is the same as Figure 1 in the Section's Comments, included here for convenience). The Section concluded from these results that the site nearest the interference source (site A on Figure 1) rapidly became useless for estimating position (even with a 1-watt radiated interference power, the C/I at site A is about -28 dB), and the location estimate depended on the TOA estimates from the other 3 sites. While in some cases, four sites are needed to provide an unambiguous location estimate, the particular case used in Teletrac's analysis should require only 3 sites. Indeed, Teletrac states that it

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2. "Impact of Co-channel Interference on 900 MHz Wideband Pulse-Ranging AVM System Performance," (Teletrac), April 6, 1992.

deliberately selected a scenario that is "almost benign." There was no multipath, and the geometry was such that GDOP (geometric dilution of precision) was not a significant factor. Consequently, as discussed in the Section's Comments, Teletrac's results seemed to suggest that the receivers at sites B, C, and D began to fail when their C/I ratios approached the neighborhood of 0 dB. This conclusion was based on the assumption that the system would disregard the TOA estimate from site A.

8. Teletrac, in Appendices 1 and 2 of its Comments, has now provided further details of its receiver performance. This new information suggests an error in the analysis in Teletrac's Petition, or worse, possibly a flaw in its system design.

9. In Figure 12 in Appendix 2 of its Comments,[3] Teletrac provides a curve showing the performance of its receiver (rms TOA estimation error vs. input carrier-to-noise ratio). According to this curve, the rms TOA estimation error is roughly described by $\sigma_t \approx 2/\sqrt{C/N}$ nanoseconds, so the corresponding ranging error is $\sigma_r \approx 2/\sqrt{C/N}$ feet. Assuming that cochannel interference affects the estimation error to the same degree as noise of equal power,[4] this receiver performance characteristic seems highly inconsistent with the results of the analysis in Appendix 2 of Teletrac's Petition. Given the receiver characteristic provided in Teletrac's Comments, the receivers at sites B, C, and D should be providing nearly exact TOA estimates, in the absence of multipath, and the large location estimation errors shown in Teletrac's Petition should not occur. The fact that they do occur suggests that the large TOA estimation error from site A is dominating the location estimate, even though an input from site A is not even necessary in this case.

10. This explanation seems to be supported by Figure 2 of these Comments, which shows the 95th percentile location error (from the analysis in Appendix 2 of Teletrac's Petition) versus the C/I at site A. The dashed line shows the rms ranging error σ_r based on the receiver characteristic given by Teletrac in its Comments.[5] Taken together, these curves suggest that if C/I exceeds roughly -25 dB, the receiver behaves

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3. "Theoretical and Field Performance of Radiolocation Systems," (June 25, 1993).
4. This is a reasonable assumption, given the spread spectrum receiver design used by Teletrac (see Appendix 1 of Teletrac's Comments, p. 19).
5. The ninety-fifth percentile would lie above the σ_r line.

in accordance with Teletrac's curve, but as C/I decreases, the receiver no longer operates "normally" and the TOA estimation error rapidly increases (this is the effect mentioned in footnote 26 on p. 21 in Appendix 1 of Teletrac's Comments[6]). Apparently, the increasingly large TOA estimation error at site A is corrupting the location estimate, leading to the increasingly large errors as the interference power continues to increase. If this is the case, then it follows that there is an error in the analysis in Teletrac's Petition, or worse, that a flaw exists in the design of the system itself. In the latter case, the result is a system more vulnerable to interference than need be. The system should be designed to recognize and reject "noisy" TOA estimates rather than allowing them to affect the location estimate.

11. Assuming that this flaw, if it in fact exists, can be remedied, the Section still believes that Teletrac's system cannot reliably operate in the 902-928 MHz band among Part 15 devices that are randomly located. In footnote 13 of its Comments, Teletrac points out that the thermal noise floor is -105 dBm (for an 8 MHz receiver bandwidth), and that Part 15 devices will not generate interference significantly above that level. On this basis, Teletrac claims that Part 15 devices do not pose a serious interference threat.

12. The Section does not agree. A Part 15 device operating under §15.247 of the Commission's Rules can transmit up to 1 watt of power and in some cases might be extremely close to a Teletrac base site. The received interference power could easily be 40 dB or more above the thermal noise floor. As an example, consider a Part 15 device with a line-of-sight path to a Teletrac base receiver half a mile away. Since the base antenna must be elevated above local terrain and buildings to provide adequate coverage, path loss between the base antenna and the Part 15 device may often vary as the square of distance (free-space propagation). At 900 MHz, the free-space path loss at half a mile is about 90 dB. If the Part 15 device is radiating 100 mW (20 dBm), the interference power into the Teletrac receiver is -70 dBm plus the base antenna gain. With a base antenna gain of 10 dBi, the received interference is -60 dBm, which is 45 dB above the thermal noise floor for an 8 MHz bandwidth (and 48 dB above the noise from for a 4 MHz bandwidth). This level of interference, according to the discussion

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6. "Engineering Analysis of Cochannel Pulse-Ranging LMS Systems," Professor Raymond Pickholtz, June 28, 1993.

in Appendix 1 (p. 10) of Teletrac's Comments is unacceptable. If the Part 15 device is radiating a full 1 watt, the interference increases by another 10 dB, to 55 dB above the noise floor.

13. It also should be noted that Teletrac seems to have changed the technical basis of its argument for exclusivity. In its Petition, Teletrac's apparent claim is that even a relatively low power (e.g., 10 watts) cochannel interference source such as a mobile unit would have a fatal effect on its system. In its Comments, however, Teletrac apparently has abandoned this line of argument and now is focusing on the effect of interference sustained from a high power (several hundred watts) transmitter on an elevated structure. This sort of interference source might represent the forward link of a competing wideband pulse-ranging AVM system operating in the same area.

14. In sum, Teletrac's submissions on this Docket, taken together, give a vague and inconsistent picture of its system's vulnerability to cochannel interference. The Section is disturbed by the apparent shift in Teletrac's technical arguments. However, even accepting the information given in Teletrac's Comments, the Section remains convinced that wideband pulse-ranging systems like Teletrac's cannot reliably coexist among the random interference that will characterize the 902-928 MHz band to an increasing degree, and that even low power Part 15 devices cannot be dismissed as non-threatening to wide area AVM systems such as Teletrac's.

RESTRICTIONS FOR LOCAL AREA AVM/LMS SYSTEMS

15. A number of Comments suggest limitations on either a combination of antenna height and transmit power, or on field strength at some specified distance from the transmitter, as possible mechanisms to define and regulate local-area AVM/LMS systems.[10] While field strength is a more accurate measure of a system's ability to interfere with other systems at a specific distance, it is more difficult to measure and enforce in a meaningful way. Fading due to multipath and shadowing effects cause large (20-30 dB) variations in received signal levels at a given distance (e.g., 1 km) from a transmitter site. The Section does not object to a field strength specification,

10. Amtech (p. 17), AT&T (p. 8), Hughes (p. 8), Mark IV (p. 13).

but believes that limitations on the combination of antenna height and transmit power are more practical to implement. A combination of a 10 meter antenna height and 30 watts ERP were suggested by several commenters. These seem reasonable for the intended applications.

16. Hughes (at p. 15) requested that for local area systems, the "tag" as well as the base station transmitters be licensed under Part 90. The Section opposes this proposal. The tags are typically either Part 15 devices themselves, or passive devices that use re-radiation (modulated backscatter) to communicate back to the base. The

19. Second, the existing Part 15 Rules governing the use of 902-928 MHz have been developed by the Commission over the course of several years and two separate proceedings, with input from the industry. As a result, a set of Rules now exists that encourages the development of new innovative technologies in the band and allows a wide variety of new and useful products, systems, and services, as clearly evidenced by the numerous applications described in the Comments of Part 15 device providers and their customers. To modify §15.247 or §15.249 at this point would devalue the many years and hundreds of millions of dollars invested in the development of systems tailored to these rules.

20. A power reduction would invalidate the link budgets of systems developed to comply with the existing Rules, and in many cases would require a total system redesign, or perhaps even render the fundamental system concept untenable. The effect of band segmentation would be somewhat more subtle but equally disastrous. The spread spectrum (direct sequence and frequency hopping) provisions in §15.247 are structured on the basis of spreading a signal over a band much wider than the information bandwidth. This requires the availability of a relatively large spectrum block to provide adequate latitude for a system to spread its signal while avoiding harmful interference. Hence, segmenting the band would necessitate a total re-work of the Rules in §15.247, which again would undermine the value of the substantial R&D effort already invested in products conforming to those Rules.

MAINTAINING THE STATUS QUO

21. A number of Comments suggested that rather than adopting the Rule changes proposed in the NPRM, the Commission maintain the status quo.[15] The Section concurs. Adopting the Rule changes proposed in the NPRM and granting AVM/LMS systems permanent status would be premature. The interference issues discussed above must be resolved, and many Comments have raised valid questions about various aspects of the technical Rule changes proposed in the NPRM. Although it is the Section's view that wideband pulse-ranging AVM/LMS systems will not be viable in the 902-928 MHz band, it has no objection to their continued use of the band as a

15. See, for example, AICC (p. 9), Part 15 Coalition (p. 5), Proxim (p. 2).

test bed on an interim basis, provided it is not at the expense of the Part 15 industry or its customers. The Section believes that eventually, either these wide area AVM systems will be judged deserving of an allocation in a band more suited to their inherent susceptibility to interference, or it will become clear that they are not cost-effective compared to alternative means of providing the same services (e.g., GPS coupled with a narrowband mobile communication link).

22. The Section therefore agrees that the only immediate solution that is fair to all involved parties is to preserve the status quo, as suggested by the Part 15 Coalition and others, but with the stipulation that AVM system operators not be allowed to force Part 15 transmitters to cease operation. This stipulation is consistent with Teletrac's claims of immunity from Part 15 device interference, and would effectively force a test of whether wideband pulse ranging AVM/LMS systems can, as Teletrac insists,

use the 902-928 MHz band as a test bed on an interim basis be prohibited from forcing Part 15 equipment operators to shut down. This requirement would test Teletrac's claim that Part 15 devices do not pose an interference threat to its system.

25. Finally, the Section strongly opposes the suggestions of several commenters that a modification of §15.247 of the Commission's Rules be considered. Not only would such modification fall outside the scope of the instant proceeding, but it would undermine years of effort in developing and refining the Rules and products to operate in compliance with them, and would devalue product designs achieved at an aggregate cost of hundreds of millions of dollars.

26. For the reasons given above, the Section urges the Commission not to adopt the Rule changes proposed in the NPRM.

Respectfully submitted,

TELECOMMUNICATIONS INDUSTRY ASSOCIATION

MOBILE & PERSONAL COMMUNICATIONS CONSUMER RADIO SECTION

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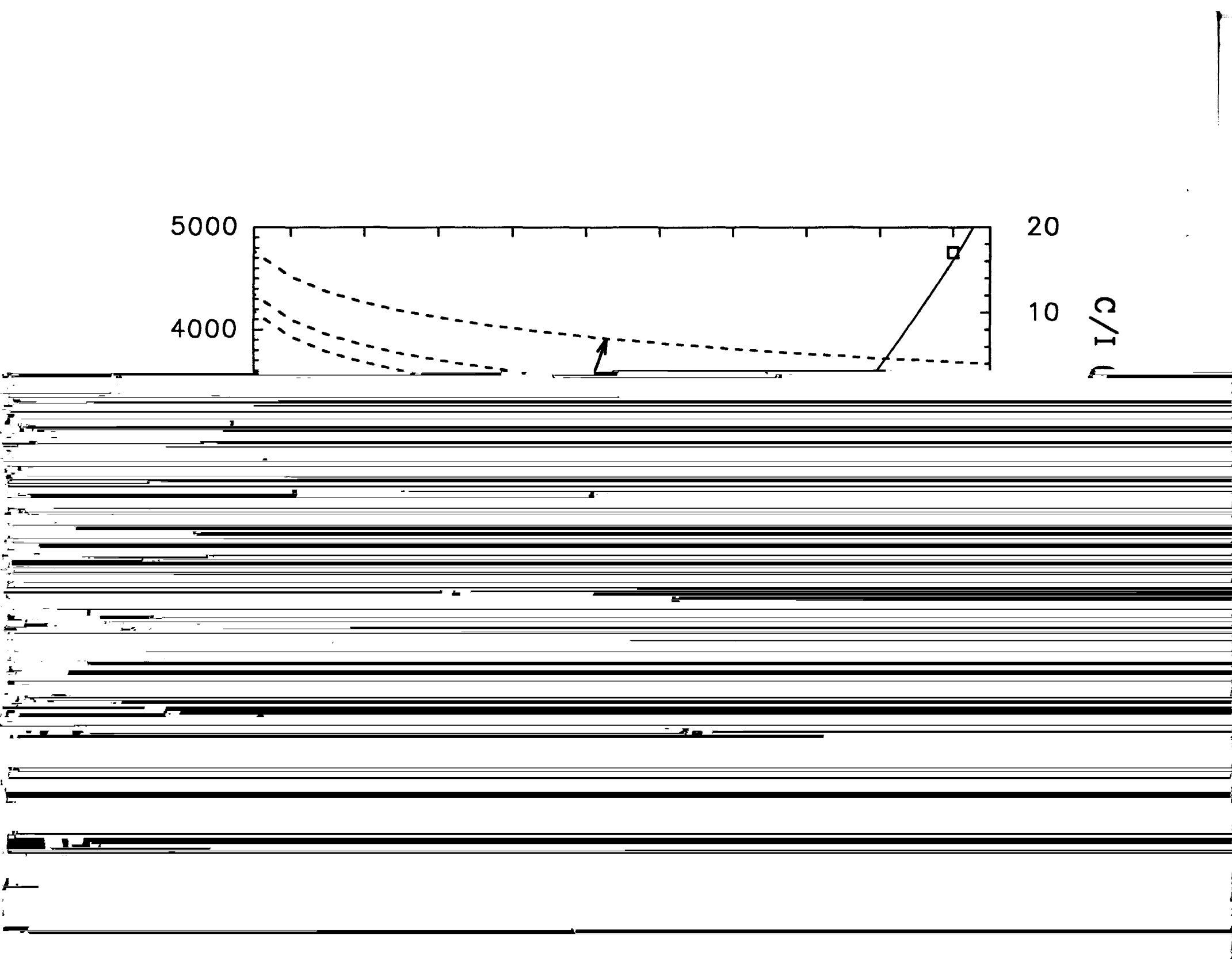
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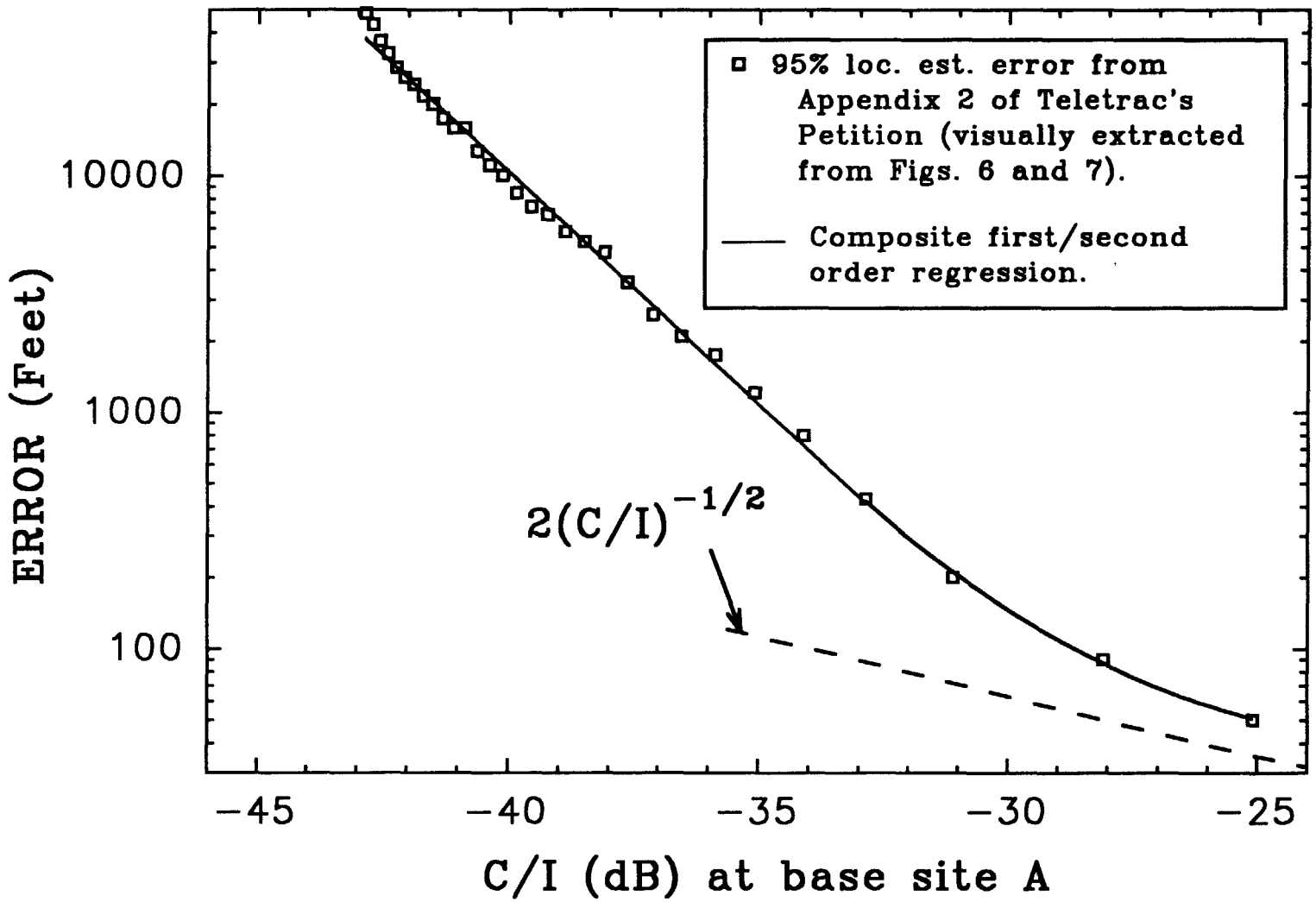
95% loc. est. error from Appendix 2 of Teletrac's Petition (visually extracted from Figs. 6 and 7).
Composite first/second order regression.
$2(C/I)^{-1/2}$
ERROR (Feet)
10000
1000
100
−45
−40
−35
−30
−25
C/I (dB) at base site A

Figure 2